Dynamics of Shallow-Water Internal Waves

Frank S. Henyey
Applied Physics Laboratory
University of Washington
1013 NE 40th Street
Seattle, Washington, 98105
phone: (206) 543-4856 fax: (206) 543-6785 e-mail: frank@apl.washington.edu
Award #: N00014-95-1-0532
http://wavelet.apl.washington.edu/OPD.html

LONG-TERM GOALS

The long-term goal is to understand the dynamics of the internal wave field on the continental shelf and in straits and fjords. Of interest are both the waves obviously generated by tides and the more random waves present between the tidally generated waves.

OBJECTIVES

We wish to find a model which captures all the main features of the observed tidally generated wave packets. The commonly used Korteweg de Vries equation is known to be adequate at very small amplitudes. We wish to know if the approximations of steadiness and neglect of dissipation on a short time scale, leading to Long's equation, can be made.

APPROACH

Various approximations to the equations of motion for a stratified fluid are investigated, and compared to data from the Solibore and Sill Flows experiment, the Coastal Mixing and Optics experiment, and others. In particular, Long's equation has been examined as a candidate model. Solutions are obtained numerically.

WORK COMPLETED

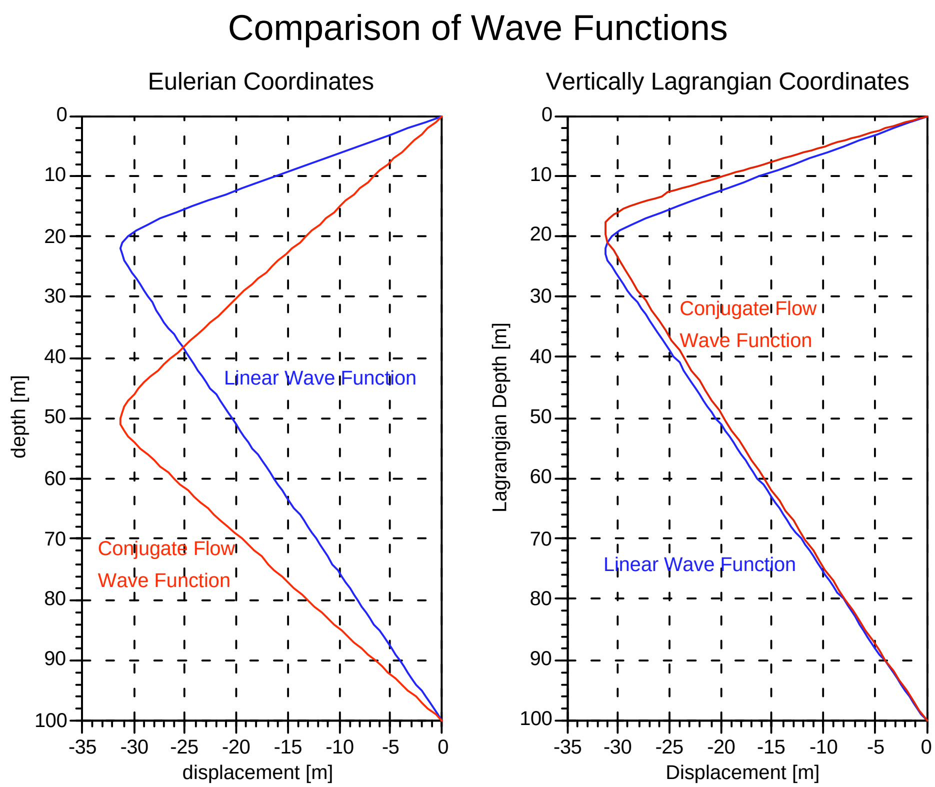
A number of solutions of Long's equation have been found. Solution of Long's equation with a strong thermocline in a small fraction of the depth required development of a numerical method different from those used with a uniform density gradient.

RESULTS

Long's equation modeling with realistic initial states has solutions that do not resemble the observed waves. In order to more closely resemble the observed waves either unsteadiness or dissipation must be important on short time scales, or there must be trapped fluid regions in the waves.

One approach to the modeling follows from a finding of K. Lamb. For conditions that resemble those in which the tidally generated packets are most often seen, he finds that the displacement wave function factorizes, to a good approximation, in a isopycnal, or vertically Lagrangian, coordinate system. For Long's equation, there is a most nonlinear wave, involving transitions to and from a unique "conjugate flow". In the figure, the test of that factorization is applied to model conditions in which there is a 5 m thick thermocline centered at 20 m depth, and the total water depth is 100 m. In the Eulerian coordinate system, the linear and conjugate flow wave functions are very different, and factorization cannot be assumed. In the vertically Lagrangian coordinate system, the wave function very closely resembles the linear wavefunction, so the factorization appears to be a good approximation.

The next step is to use this factorization in a variational ansatz, using the canonical Hamiltonian theory of stratified fluid dynamics. This approach still assumes the neglect of dissipation, so we do not yet know whether it will be successful.



The wavefunctions for linear and most nonlinear waves in Long's equation are compared. In the vertically Lagrangian frame they are nearly equal, allowing

IMPACT/APPLICATIONS

High amplitude internal waves in coastal oceans are important in a number of ways. They profoundly modify the propagation of sound, and the currents associated with them can affect many marine operations. They may be important in transporting plankton and other substances. The associated non-Gaussian statistics of the coastal internal waves requires a modification to deep-ocean methods of understanding ocean processes and features that depend on internal waves.

RELATED PROJECTS

The Synthetic Aperture Sonar Primer experiment, associated with the Coastal Mixing and Optics program, investigated the effects of coastal internal waves on high-frequency acoustic transmission. The dynamical understanding of the internal waves is crucial for interpreting the acoustics data.

The Solibores and Sill Flows experiment investigated the high-amplitude internal waves in a fjord.

There are a number of projects by various investigators that have measured coastal internal waves in a variety of geographical regions. Close contact between all the investigators http://www.whoi.edu/science/AOPE/people/tduda/isww is essential for making progress on understanding these waves.